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Waist circumference as a determinant of hypertension and diabetes in Brazilian women: a population-based study

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Abstract

Objective: To evaluate the role of central adiposity, as evaluated by the measurement of waist circumference (WC), as an independent risk factor for hypertension and type 2 diabetes mellitus in the setting of a developing country.
Design: Population-based, cross-sectional study.
Setting: A medium-sized town in southern Brazil.
Participants: One thousand and ninety-five non-pregnant women, 20 to 69 years old, recruited by cluster random sampling between 1999 and 2000. Their mean WC was 85.3 cm (standard deviation 13.9 cm) and 23.3% ($n = 255$) were obese (body mass index $>30\,\mathrm{kg\,m^{-2}}$). The prevalence of hypertension and diabetes was 25.6% ($n = 280$) and 6.2% ($n = 68$), respectively.
Results: The risks of hypertension and diabetes were directly related to WC measurement. Women with WC > 80 cm had increased risk of hypertension (odds ratio (OR) = 6.2, $P < 0.001$). The association remained significant (OR = 1.04 per cm increase in WC, $P = 0.02$) after adjusting for confounders. The effect of WC on diabetes was modified by age. The effect was stronger in women younger than 40 years old (OR = 12.7, $P = 0.016$) than in those over 40 years old (OR = 2.8, $P = 0.013$). In the multivariate analysis, the odds ratio was 5.7 ($P = 0.12$) in those under 40 years old and 2.8 ($P = 0.008$) in older women.
Conclusions: Waist circumference is an independent determinant for hypertension and diabetes in women in this population. The stronger association between WC and diabetes in younger women suggests that the validity of this indicator to assess abdominal adiposity is age-specific. Further studies should validate the usefulness of WC measurement in different age groups.

Keywords
Waist circumference
Hypertension
Diabetes mellitus
Population-based study

The associations of increased weight and body fat composition with non-communicable diseases, particularly cardiovascular diseases and diabetes, are well established[1].

Body fat distribution has been measured using a range of techniques, such as computerised tomography (SPECT scan), magnetic resonance imaging and ultrasound. However, these methods have low efficiency in population-based epidemiological studies. Various anthropometric measures have also been used for the purpose but represent different aspects of fat distribution, and thus relate differently to health outcomes[2–4]. Of these, waist circumference (WC) is recommended as being a practical and reliable method to assess abdominal fat at a population level[5,6]. Compared with other measures, such as waist/hip ratio, body mass index (BMI) and hip measurement, WC has been shown to be a suitable indicator of abdominal adiposity and a surrogate of visceral adipose tissue in adults[7–11].

A direct relationship between WC and morbidity risk has been shown in some population groups[4,12–17]. However, while the generalisability of the findings from existing studies to populations in many developing countries is unclear, little information is available for women living in such areas, particularly from population-based studies. It would be particularly relevant to study populations of different 'cultural status', which may influence not only waist size[18] but also its association with morbidity[19].

In the present paper, we report the results of a population-based, cross-sectional study conducted among non-pregnant women from southern Brazil. The study used a conceptual analysis model[20] to assess the independent effect of WC on hypertension and diabetes in this population.

Methods

Between December 1999 and April 2000, a population-based, cross-sectional study conducted in Pelotas,

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southern Brazil collected information on 846 men and 1102 women (over 90% of the eligible individuals). This report refers to the 1095 non-pregnant women between 20 and 69 years old in the sample, for whom complete anthropometric information on WC and BMI was available. Written informed consent was obtained from all participants. Ethical clearance was obtained from the Faculty of Medicine of the University of Pelotas Ethical Committee.

Women were randomly recruited by cluster sampling, where the primary sampling units were 40 systematically selected census areas in Pelotas[21]. In each census area, a random starting point was selected. Following a pre-determined direction, one in every three households was chosen until the sample of 30 households with eligible subjects was reached. All women aged 20 to 69 years living in the selected houses were invited to participate in the study. Trained staff conducted face-to-face interviews in the participants' homes and obtained information on demographic, socio-economic and behavioural variables. These were complemented by measurements of weight and height, which followed recommendations of the World Health Organization[22], and of WC or the minimum circumference between the rib cage and the iliac crest. The latter was obtained with an anthropometric tape applied directly to uncovered skin, with the woman standing and at the end of expiration. Blood pressure was taken twice in the left upper arm using an aneroid sphygmomanometer and stethoscope. Measurements were taken 15 min apart with women resting in the seated position.

A diagnosis of hypertension required either a mean blood pressure from two measurements above 160 mmHg (systolic) or 95 mmHg (diastolic), or report of the use of anti-hypertensive agents. Diagnosis of diabetes was clinical, as reported by the women. Venous blood samples were taken from a random sub-sample of 216 women, selected systematically, for analysis of plasma glucose (Birck Laboratories Ltd, Pelotas, Brazil). This was used to validate the diagnosis of diabetes.

Data collection instruments were pre-tested, interviewers carefully trained and procedures standardised. Supervision of fieldwork included re-interviews of 10% of the sample, using a simplified questionnaire.

The sample size chosen for the study was adequate to detect, with >85% power at the 5% significance level, odds ratios (ORs) of 2 and above, assuming prevalence of exposure between 20 and 60%. This calculation considered an extra 20% for multivariate analysis (Sample power2.0; SPSS Inc., Chicago, IL, USA).

Data were double-entered using Epi-Info 6.0 (Centers for Disease Control and Prevention, Atlanta, GA, USA) and analysed in STATA 7.0 (Stata Corp., College Station, TX, USA) according to a pre-established analysis plan. Univariate and multivariate logistic regression analyses[23] were used to calculate ORs and 95% confidence intervals (CIs).

WC was analysed as both a continuous and a dichotomous variable, using 80 cm as the cut-off point in most analyses[12]. BMI was used to classify women as 'normal or slim' ($<25\,kg\,m^{-2}$), 'overweight' (≥ 25 and $<30\,kg\,m^{-2}$) or 'obese' ($\geq 30\,kg\,m^{-2}$).

For the multivariate analysis, a theoretical conceptual model was defined *a priori*[20]. The decision of which variables to include in the model was based on a conceptual framework describing hierarchical relationships between risk factors. The model considered age and skin colour as distant determinants (level 1), i.e. those affecting the outcome directly or indirectly through other groups of risk factors. The second level included socio-economic variables, which may be affected by variables in level 1 and may affect variables in subsequent levels (3 and 4). Anthropometric indicators were considered the most proximate factors, in level 4 (Table 1). It is important to note that a variable is not adjusted by any variable in subsequent levels, as these may mediate the effects of the former on morbidity, but not confound them. Inclusion of variables into the model at each level was decided by the finding of $P < 0.1$ in the likelihood ratio test comparing models with and without the variable. Association of exposures and outcomes was tested firstly in level 1, with the subsequent 'inclusion' of exposures in further levels. Variables found to be significantly associated with the outcome within its level were kept in the model throughout, even if significance was lost when variables from subsequent levels were added.

Results

Of the 1102 non-pregnant women recruited for the study, seven (0.6%) did not have complete information on anthropometric measures. Therefore the results presented here refer to 1095 women for most analyses related to diabetes. A further three subjects had missing information on blood pressure; thus the total sample of 1092 was used for analyses involving the outcome hypertension.

Women in the sample had a mean age of 42 years and attended school for 7.8 years on average. Most were white (83.2%), around 50% were in a stable relationship, 28%

Table 1 Variables included in the conceptual analysis model by level

Level	Characteristic	Variable
Level 1	Demographic	Age Ethnic origin (skin colour)
Level 2	Socio-economic	Years of schooling Income Social class Marital status
Level 3	Behavioural	Smoking Alcohol ingestion
Level 4	Anthropometric	Body mass index Waist circumference

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were current smokers and 3.6% were heavy drinkers (more than 30 g of alcohol per day).

Women weighed on average 65.4 kg (standard deviation (SD) 13.8 kg) and had a mean height of 157.3 (SD 6.3) cm. Their mean BMI was 26.5 (SD 5.5) $kg\,m^{-2}$ and 23.3% ($n = 255$) were obese (BMI $\geq 30\,kg\,m^{-2}$). Women's mean WC was 85.3 (SD 13.9) cm. WC and BMI were highly correlated (Pearson's $r = 0.85$; $P < 0.001$). The sensitivity and specificity of WC > 80 cm as a predictor of obesity (BMI $\geq 30\,kg\,m^{-2}$) were 91% and 77%, respectively ($P < 0.001$).

The prevalence of hypertension and diabetes was 25.6% ($n = 280$) and 6.2% ($n = 68$) respectively. Of those with glycaemia results ($n = 216$), 208 had fasting plasma glucose below $140\,mg\,dl^{-1}$, of whom 194 did not refer to diabetes. We assumed that most of the 14 women referring to diabetes had their condition under control and therefore do not represent false negatives. This yields a specificity for reported diabetes of over 93%, most likely near 100%. Half of the eight women with fasting plasma glucose above $140\,mg\,dl^{-1}$ did not report diabetes, suggesting a sensitivity of approximately 50%, which probably applies equally to individuals exposed and not exposed to the various risk factors.

Variables associated with hypertension in the univariate analyses are shown in Table 2. The risk of hypertension was directly related to age and inversely related to years of schooling. Hypertension was also associated with skin colour and marital status. Moderate drinking and current smoking appeared to have a protective effect.

The risk of hypertension was directly associated with BMI and WC. Increased risk was noted both for WC > 80 cm (OR = 6.2, 95% CI 4.3–9.0) and WC > 96 cm (cut-off point corresponding to the 80th percentile in this population) (OR = 4.6, 95% CI 3.4–6.3). A linear effect of WC on hypertension was noted, with an OR of 1.07 (95% CI 1.06–1.08) for each cm increase in WC.

In the final model, the prevalence of hypertension was also associated with increasing age and decreasing years

Table 2 Univariate analyses of risk factors for hypertension ($n = 1092$)

		Hypertension		
Variable*	*n* (%)†	OR	95% CI	*P*-value
Age group (years)				
20–29	220 (5.45)	1		<0.001
30–39	262 (10.69)	2.07	1.03–4.18	
40–49	258 (27.91)	6.71	3.53–12.75	
50–59	222 (53.08)	13.95	7.36–26.44	
60–69	130 (53.08)	19.61	9.97–38.55	
Skin colour				
White	910 (24.84)	1		0.037
Mixed	76 (21.05)	0.81	0.46–1.42	
Black	106 (35.85)	1.69	1.11–2.58	
Marital status				
Single	236 (13.98)	1		<0.001
Married/with partner	627 (26.32)	2.20	1.46–3.31	
Separated	120 (30.00)	2.63	1.54–4.51	
Widowed	183 (15.85)	4.49	2.65–7.62	
Years of schooling				
0–4	294 (41.16)	1		<0.001
5–8	331 (22.96)	0.43	0.30–0.60	
9–11	284 (19.01)	0.34	0.23–0.49	
> 11	183 (15.85)	0.27	0.17–0.43	
Smoking				
Never	598 (27.09)	1		0.004
Former smoker	191 (31.41)	1.23	0.86–1.76	
Current smoker	303 (19.14)	0.64	0.45–0.89	
Alcohol ingestion				
No	327 (31.19)	1		0.021
Yes, $<30\,g\,day^{-1}$	717 (23.01)	0.66	0.49–0.88	
Yes, $\geq 30\,g\,day^{-1}$	39 (25.64)	0.76	0.36–1.62	
WC				
≤ 80 cm	439 (8.66)	1		<0.001
> 80 cm	653 (37.06)	6.21	4.30–8.98	
WC (as a continuous variable)	–	1.07‡	1.06–1.08	<0.001
BMI ($kg\,m^{-2}$)				
< 25	501 (11.59)	1		<0.001
25–30	339 (30.09)	3.28	2.30–4.71	
≥ 30	252 (47.62)	6.94	4.80–10.04	

OR – odds ratio; CI – confidence interval; WC – waist circumference; BMI – body mass index.
* Variables not associated with hypertension in the univariate analysis: income and social class.
† Number of women in each variable category and percentage with hypertension in each category.
‡ For each cm increase in WC.

Table 3 Final adjusted model for the effect of waist circumference (WC) on hypertension ($n = 1092$)

	Hypertension		
Variable*	OR (adjusted)	95% CI	*P*-value
Level 1†			
Age group (years)			
20–29	1		<0.001
30–39	1.97	0.97–3.98	
40–49	6.71	3.52–12.78	
50–59	13.85	7.30–26.29	
60–69	19.64	9.97–38.70	
Skin colour			
White	1		0.018
Mixed	0.87	0.47–1.63	
Black	1.97	1.22–3.17	
Level 2‡			
Years of schooling			
0–4	1		0.014
5–8	0.70	0.48–1.02	
9–11	0.72	0.47–1.11	
> 11	0.46	0.28–0.77	
Level 3§			
Smoking			
Never	1		0.032
Former smoker	1.46	0.97–2.19	
Current smoker	0.79	0.53–1.16	
Level 4¶			
WC (as a continuous variable)	1.04‖	1.02–1.06	< 0.001

OR – odds ratio; CI – confidence interval.
* The following variables were excluded from the model (using the likelihood ratio test): marital status, social class, income and body mass index (BMI).
† Adjusted for variables in the same level (age and skin colour).
‡ Adjusted for variables in the same level (marital status) and for variables in level 1.
§ Adjusted for variables in the same level (alcohol ingestion) and in levels 1 and 2.
¶ Adjusted for variables in the same level (BMI) and in levels 1, 2 and 3.
‖ For each cm increase in WC.

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of schooling, skin colour (increased risk in blacks) and smoking (increased risk among ex-smokers) (Table 3). The association between WC (as a continuous variable) and hypertension remained significant (OR = 1.04, 95% CI 1.02–1.06) after controlling for confounders.

Table 4 shows variables associated with diabetes in the univariate analyses. A higher risk of diabetes was observed with increasing age, decreasing level of education, among those of mixed ethnic origin and among married and widowed women. Both BMI and WC were directly and highly significantly associated with diabetes. The odds of diabetes were 8.5 times higher in obese compared with normal or slim women. Each cm increase in WC increased the odds of diabetes by 6% (OR = 1.06, 95% CI 1.04–1.07). The ORs corresponding to WC > 80 cm and >96 cm were 5.4 (95% CI 2.6–11.5) and 5.3 (95% CI 2.6–11.4), respectively.

The following variables remained significantly associated with diabetes in the multivariate analysis: age group, BMI, WC (direct association) and skin colour (higher risk in those of mixed ethnic background) (Table 5). An interaction was found between age and WC, with a stronger effect of WC on diabetes in those under 40 years old in the bivariate analysis (OR = 12.7, 95% CI 1.6–101.2; $P = 0.002$) and multivariate analyses (OR = 5.7, 95% CI 0.6–51.0; $P = 0.12$). The odds in those older than 40 years were 2.8 (95% CI 1.3–5.8; $P = 0.006$) and 2.9 (95% CI 1.3–6.1, $P = 0.008$) in the bivariate and multivariable analyses, respectively (Table 5).

Discussion

This population-based study was designed to evaluate the effect of waist circumference on hypertension and diabetes in the setting of a developing country. Using multivariate analysis based on a conceptual model, we found WC to be associated with both hypertension and diabetes. In the case of diabetes, this association was modified by age.

The conceptual model allowed us to study disease determination respecting the direction of relationships between social and biological variables[20]. Previous studies, although controlling for confounding variables, have not taken into account the conceptual hierarchy of risk factors[13,24–28], therefore risking undue control of variables that are not confounders.

Table 4 Univariate analyses of risk factors for diabetes ($n = 1095$)

		Diabetes		
Variable*	*n* (%)†	OR	95% CI	*P*-value
Age group (years)				
20–29	220 (1.82)	1		<0.001
30–39	263 (2.28)	1.26	0.35–4.53	
40–49	259 (3.86)	2.17	0.67–7.01	
50–59	223 (10.31)	6.21	2.11–18.27	
60–69	130 (19.23)	12.86	4.36–37.89	
Skin colour				
White	911 (5.38)	1		0.020
Mixed	77 (14.29)	2.93	1.46–5.91	
Black	107 (7.48)	1.42	0.65–3.09	
Marital status				
Single	237 (3.38)	1		0.005
Married/with partner	627 (7.02)	2.16	1.00–4.66	
Separated	120 (2.50)	0.73	0.19–2.82	
Widowed	111 (11.71)	3.80	1.53–9.45	
Years of schooling				
0–4	295 (11.86)	1		<0.001
5–8	332 (5.72)	0.45	0.25–0.81	
9–11	284 (2.82)	0.22	0.10–0.47	
> 11	184 (3.26)	0.25	0.10–0.61	
WC				
≤ 80 cm	439 (1.82)	1		<0.001
> 80 cm	656 (9.15)	5.42	2.57–11.46	
WC (as a continuous variable)	–	1.06‡	1.04–1.07	<0.001
BMI (kg m^{-2})				
< 25	501 (2.20)	1		<0.001
25–30	339 (4.72)	2.21	1.01–4.82	
≥ 30	255 (16.08)	8.53	4.30–16.92	

OR – odds ratio; CI – confidence interval; WC – waist circumference; BMI – body mass index.
* Variables not associated with diabetes in the univariate analysis: income, social class, smoking and alcohol ingestion.
† Number of women in each variable category and percentage with diabetes in each category.
‡ For each cm increase in WC.

Table 5 Final adjusted model for the effect of waist circumference (WC) on diabetes ($n = 1095$)

	Diabetes		
Variable	OR (adjusted)	95% CI	*P*-value
Level 1*			
Age group (years)			
20–29	1		<0.001
30–39	1.32	0.37–4.77	
40–49	2.40	0.74– 7.80	
50–59	6.54	2.20–19.38	
60–69	14.20	4.77–42.31	
Skin colour			
White	1		0.01
Mixed	3.42	1.62–7.22	
Black	1.46	0.65–3.27	
***Level 2*†**			
Marital status			
Single	1		0.10
Married/with partner	1.76	0.77–4.04	
Separated	0.56	0.14–2.25	
Widowed	1.15	0.42–3.10	
***Distal level*‡**			
BMI (kg m^{-2})			
< 25	1		0.02
25–30	1.21	0.53–2.78	
≥ 30	2.90	1.19–7.07	
WC (as a continuous variable)	1.02¶	1.00–1.05	0.048
***Evaluation of interactions*§**			
Age <40 years & WC > 80 cm	5.67	0.63–51.01	0.122
Age ≥40 years & WC > 80 cm	2.85	1.32–6.14	0.008

OR – odds ratio; CI – confidence interval; BMI – body mass index.
* Adjusted for variables in the same level (age and skin colour).
† Adjusted for variables in the same level (years of schooling) and in level 1.
‡ Adjusted for variables in the same level (BMI, WC) and in levels 1 and 2.
§ Adjusted for variables in the same level (BMI, WC and interaction age × WC) and in levels 1 and 2.
¶ For each cm increase in WC.

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The prevalences of hypertension and diabetes were similar to those described for adult women in the region[29–31]. Average BMI and WC were slightly higher in this study compared with another study in Brazil among women of reproductive age[32].

We found that the risk of hypertension was higher with increasing WC and age and in black women. Lower level of education and previous smoking (borderline) were associated with a higher risk. The apparently protective effect of current smoking is likely to reflect that some may give up smoking following a diagnosis of hypertension. WC was found to be a stronger determinant of hypertension than BMI.

Our results are consistent with other studies showing an association of WC and cardiovascular disease[13,24], which is stronger than that for other anthropometric indicators[4,27]. Some studies have specifically shown WC to have an independent effect on hypertension risk[17,25,26].

In this population, diabetes is more likely to affect older, non-white women with large WC and increased BMI. The association between WC and type 2 diabetes in women has been reported in various studies[25,28,33,34]. However, the waist size associated with increased risk was variable, with cut-off points of 84 cm[28] and 88 cm[34] being suggested as the most appropriate. We found a linear effect of WC on diabetes risk and significant associations when both 80 cm and 96 cm were used as cut-off points for the variable WC. BMI remained associated with diabetes in the final model, suggesting a residual effect of excessive weight on the risk of diabetes that is independent of visceral adiposity.

Our study also suggested that age modifies the effect of WC on diabetes (with stronger effects in younger women), but not on hypertension. Similar results (on diabetes) had been shown for American Japanese women[33]. A study among Americans from various ethnic groups[35] also found that, in the young, excess weight (BMI) is more strongly associated with co-morbidities, including type 2 diabetes. These findings could be supported by the age specificity of the relationship between anthropometric variables and visceral adipose tissue accumulation[8]. WC is likely to be more closely linked to visceral adiposity in the young than in the elderly, among whom it may partially reflect changes related to the ageing process other than adipose tissue accumulation[33]. WC, although probably the best anthropometric predictor of visceral fat[7,36], has been suggested to be a less useful indicator of visceral fat in older people[37], among whom its interpretation may be more complex.

A representative sample of the population was selected for the study. Non-response occurred in a small proportion of the intended sample and is unlikely to have caused selection bias or affected the generalisation of the results. We expect a very good reliability of the diagnosis of hypertension. We were also careful in the collection of information on history and treatment for diabetes. However, for logistic reasons, we were not able to collect blood samples from all women. A report of diabetes diagnosed by a doctor may be considered good evidence of diabetes, i.e. has a high specificity. On the other hand, the sensitivity of women's reports is unlikely to be high, as many diabetics may be unaware of their condition. There is no theoretical reason to suggest that report of diabetes would vary according to the main exposures in the study, i.e. the possible misclassification would be non-differential. This may have resulted in a reduction in the power to detect significant associations between diabetes and risk factors or a reduced size of the OR. We included data on relevant variables that could act as confounders in the association of interest. However, we did not include variables such as physical activity and family history of hypertension and diabetes. We excluded these variables because reverse causality would certainly have been a problem in the interpretation of the relationships with the former, and we considered the latter not to be reliable data to obtain by history in this population.

The results of the regression analyses are expressed in terms of odds ratios, which were chosen for consistency between univariate and multivariate analyses. These are slightly higher than prevalence ratios, particularly for common outcomes such as hypertension, but are less different from these for less common outcomes like diabetes. Although reverse causality is often a problem in the interpretation of cross-sectional studies, which limits their use in the study of disease determination, the use of a conceptual model approach for the multivariate analysis, by taking into account the direction of operation of risk factors, minimises this problem. For example, the model assumes a unidirectional relationship between age group (a level 1 variable) and years of schooling (a level 2 variable), meaning that age may influence years of schooling but cannot be influenced by it. As a consequence, the effect of years of schooling on the outcomes takes into account the possible confounding by age, but the effect of age on the outcomes is necessarily independent of years of schooling. Previous studies give confidence on the direction of the association between WC and the outcomes of interest, i.e. hypertension and diabetes[25,33]. In the case of diabetes, for example, the increased mass of metabolically active visceral adipose tissue leads to insulin resistance and glucose intolerance, which are well established precursors of diabetes[38].

Although more accurate methods to determine the effect of central adiposity on some chronic diseases are available[39], WC measurement remains a useful and practical tool for identifying risk in population-based studies, especially in places where financial resources are scarce. The findings of this study, which apply to a developing country population, are consistent with those of other studies showing an independent association of central adiposity and high blood pressure and diabetes.

Therefore our results provide additional support for an independent role of WC in the determination of both hypertension and diabetes in adult women.

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